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THE WITHERING OF TEA LEAF.

BY

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In the following discussion of the withering of tea leaf, it is proposed first to describe briefly some of the chemical and physical changes which take place during the withering process. Some account will next be given of the formation of red tannin bodies when undamaged tea leaf is submitted to high temperatures. The practical aspect of withering will then be considered and an account of attempts made to control the withering process in North East India will be discussed.

1. CHANGES IN THE LEAF DURING WITHERING.

Chemical changes.

Slight chemical changes take place in the tea leaf during withering.

After the leaf is plucked, and whilst it is withering, it continues to respire. In respiration, oxygen from the air is absorbed by the leaf and carbonic acid gas discharged. Approximately equal volumes of gas are taken in and expelled by the leaf, and since carbonic acid gas is heavier than oxygen, it follows that there will be a loss in weight of the solid matter in the leaf as withering proceeds.

This loss is considerable. Thus 100 lbs. of average leaf when plucked contains about 77 lbs. moisture and 23 lbs. solid matter. When this weight of leaf has been suitably withered it contains about 22 lbs. solid matter, the decrease, amounting to about 5% of the total, being mainly due to respirational changes.

Whilst the leaf is growing on the bush the photosynthetic manufacture of starches and gums proceeds simultaneously with the breaking down of such bodies to simpler, soluble bodies like sugars. After the leaf is plucked photosynthesis almost ceases, although the breaking down of the starches and gums proceeds.

Accordingly, during withering there is a decrease in the starch and gummy matter in the leaf and an increase in the sugars.

Another chemical change occurring during withering is a slight increase the water soluble nitrogenous compounds.

About one-third of the solid matter of the leaf consists of nitrogenous compounds which include caffeine, proteins and simpler protein bodies. When tea leaf or tea is extracted with hot water the caffeine and simpler protein bodies dissolve, but the proteins themselves are insoluble. During withering, some of the proteins are broken down to simpler protein bodies which are soluble in water. Hence, as recorded above, there is a slight increase in water soluble nitrogenous bodies in the leaf during withering.

The decomposition of proteins and the changes in the content of starch and gums of the leaf, already described, are probably of no practical importance in tea manufacture.

It has been assumed in this Department for some years that, during withering an important chemical change takes place in the leaf. The change was considered to consist of the hydrolysis of a tannin glucoside, which was thought to be present in fresh tea leaf, and was spoken of as the "chemical wither". The hypothesis has proved useful as a working basis, but has now been discarded because no evidence of the presence of a sugar in the tea tannin molecule has been obtained.

During withering, the fruity odour of the leaf increases. This may or may not be of importance in itself, but it indicates that minor changes are occurring, and some of these may be important. Thus, as described later, it is possible that changes connected with the formation of the essential oil of tea may take place during withering.

Physical changes.

The obvious change in withering is the loss of moisture from the tea shoot, and the amount of this loss is taken as a measure of the degree of the wither in practice.

Moisture is not lost from all parts of the shoot at an even rate. In a soft shoot with a thick bud, most of the water is lost from the first and second leaves and that from the bud and stalk passes from the shoot by way of these leaves. This movement of water within the shoot is rather slow, and rapid withering is liable to dry out and blacken the soft leaves before moisture has been translocated from the other parts of the shoot. On this account a slow wither is necessary for the even drying of all parts of the shoot.

These points are illustrated in the table below, which shows the course of drying of mid-season shoots when withered rapidly and slowly, respectively. The leaves were thin and both first and second leaves lost water freely. With the rapid, 2-hour wither many of the leaves turned black. The buds were thick and unable to lose water directly at as rapid a rate as the leaves.

Table showing the effect of the rate of wither on distribution of water in tea shoot.

	Fresh leaf.	Shoots withered in 2 hours.	Shoots withered in 24 hours.
	Moisture %	Moisture %	Moisture %
Bud	78·3	71·1	65·2
First leaf	76·3	60·6	64·0
Second leaf	76·2	55·8	65·8
Stalk	84·7	79·2	73·0
Whole shoot	79·4	67·8	67·3

When a shoot is withered rapidly for a short time and then slowly for some hours, it is often noticed that the flaccid (withered) leaves appear to regain some of their original turgidity. This is due to the fact that moisture is sent from the stalk and bud to the leaves. If, in the rapid-drying period, the leaves reach an extreme state of flaccidity then the translocation of water may no longer be possible and a degree of turgidity is not regained.

When leaf grows slowly or when leaf ages or turns into a hard *banjhi* it loses its capacity for rapid withering. Thus with hard shoots plucked at slow growing periods, most of the moisture

is lost from the first leaf and the bud, which latter is generally thin in such cases, and able to dry directly.

With coarse shoots of three or more leaves and a bud, the third and lower leaves do not directly lose their moisture with great ease, but wither largely by transferring moisture to other parts of the shoot. A coarse shoot is only withered evenly if it withers slowly, and in a withering period of 18 hours or so, the third leaf of a shoot is usually still turgid.

A *banjhi* leaf when hard has no power of rapid withering and, bereft as it is of any soft leaf, may remain for days without drying sufficiently to lose the shiny appearance of its upper surface. An inspection of leaf after some hours withering clearly distinguishes the hard and soft shoots. The former still retain their glaze, which denotes turgidity, whilst the latter have assumed the dull, soft appearance which goes with a flaccid leaf.

It is instructive to separate shoots into their component parts, first and second leaves, bud and stalk, and to wither these parts separately and compare the rate of drying with the rate shown by the whole shoot. The table below shows what may be expected of May leaf, plucked during a slow growing period, with a hard second leaf and a small, thin bud, capable of freely losing moisture directly. The rate of drying of the component parts of the shoot may be contrasted with that shown by the mid-season shoots used in the previous table.

The withering of tea shoots whole and separated into component parts.

	Fresh leaf.	Withered as whole shoot.	Parts withered separately.
	Moisture %	Moisture %	Moisture %
Bud	74·1	52·4	54·1
First leaf	72·4	50·6	53·6
Second leaf	72·5	53·3	58·4
Stalk	82·2	62·8	80·0
Whole shoot	76·7	57·7	56·2

It will be observed that the stalk, when separated, withers hardly at all. When it is attached to the shoot its moisture content falls from 82.1 to 62.8%, a drop of about 20%, comparable with the change observed in other parts of the shoot.

Mention may here be made of the general impression amongst planters that very young shoots or immature leaf will not make good tea. This may be so, but the reason is probably not that such leaf is lacking in qualities which develop as the shoot matures, but because it is practically impossible to wither immature leaf satisfactorily. A shoot when it is just formed has very thin leaves which wither too rapidly for it to be manufactured successfully with normal shoots which take a much longer period to wither.

A shoot of one leaf and a bud often withers unevenly because it lacks the stabilising influence of a second leaf. The result is that the single leaf often blackens whilst the bud is still turgid.

In order to make good black tea the leaf must be withered.

The reason for withering.

The reason for withering is not wholly clear. The chemical changes concerned, so far as they have been estimated, appear to be small and unimportant. The physical need for withering is obvious because fresh leaf will not roll easily, and custom demands a tea with a twisted leaf. More important is the fact that flaccid *i.e.* withered, leaf is more damaged in rolling than turgid or fresh leaf. The more damage a leaf receives in rolling the more are the juices exposed to the air during fermentation or oxidation.

Experiment has shown that well withered leaf on rolling absorbs more oxygen than unwithered or lightly withered leaf. This results from the more complete rupture of the leaf cells and a greater exposure of the juice. It might be argued that, if the chemical changes in withering are negligible, then sufficient rolling or mashing of fresh, unwithered leaf should give as good liquors as ordinarily rolled withered leaf. Admittedly the appearance of the finished tea would suffer in the former case and much leaf juice would be lost in rolling.

In order to observe the effect of withering, tea was made from leaf fresh from the bush and from similar leaf normally withered. When these teas were exhaustively extracted with boiling water for an hour about the same amount of tannin, caffeine and soluble solids were extracted in both cases. When infused for 5 minutes, however, the tea made from withered leaf gave more soluble solids and tannin than the other tea. Hence, withered leaf appears to give a tea which is more easily extracted than tea made from fresh leaf.

The two teas just described were examined by a tea taster who described one (that from withered leaf) as "good tea" and the other as "characterless" and "just tea". The thinness of liquor (low soluble solids) or "rawness" were not remarked upon, the main point being lack of tea characteristics.

The fact that the unwithered leaf gave a tea lacking in properties peculiar to tea suggests that tea aroma and flavour, properties usually associated with the essential oil of tea, were missing. It is thus possible that, during withering, certain reactions go on or certain conditions are brought about which make for the development, during fermentation, of the essential oil responsible for the tea aroma.

During withering, the physical state of the leaf colloids changes. Since fermentation is concerned with these colloidal substances, it is probable that their physical state will influence the course of fermentation. The change taking place in the colloidal state will be dependent on the rate of drying of the leaf and the temperature at which it is dried. In this manner some of the characteristics of the tea made will be influenced by the way in which the leaf is withered.

2. The Formation of Tannin "Reds".

Phlobaphenes and tannin "reds."

Tea tannin, like other tannins of its class, is able to form water-insoluble substances called phlobaphenes or "reds". These bodies are red or brown in colour and result from the oxidation or condensation of tannin. The phlobaphenes formed by the

oxidation of tea tannin are of great interest since they, and other tannin oxidation products, result from the oxidation of tea tannin during the fermentation process. A study of these bodies must be reserved to a discussion of tea fermentation.

The phlobaphenes which result from the condensation of the tannin molecule, apart from oxidation, are probably not formed to any great extent in tea manufacture, except when conditions are bad. The terms phlobophene and "red" are used interchangeably by leather chemists to indicate the tannin products of either oxidation or condensation.

In order to distinguish between the two sets of compounds which are, in tea chemistry, of such importance, it has been decided here, for the sake of convenience, to use the term "red" to denote a condensed tannin products and phlobaphene to denote an oxidation product.

Both phlobaphenes and "reds" can easily be produced either in fresh tea leaf infusions or in tea leaf. Oxidation products may be formed by making a leaf infusion alkaline. Thus when sodium carbonate is added to an infusion it immediately turns dark brown, oxygen is absorbed and tannin is lost. During tea manufacture, oxidation products are formed by the aid of an enzyme in the leaf when the latter is rolled and the juice exposed to air. If leaf is rolled *in vacuo* no oxidation takes place, and it remains green.

The condensation product or tannin "red" may be formed in a tea leaf infusion by boiling it with 5% sulphuric acid. The infusion rapidly turns red and after some time a precipitate of tannin "red" is formed and tannin is lost.

"Reds" may be formed in tea leaf when the latter is heated. The formation of "reds" does not require oxygen and the reaction proceeds *in vacuo* the same as in air. The formation of "reds" under the influence of heat will be discussed in some detail.

When the leaf is heated to 160°F. for a few minute it turns olive green and is killed. Such leaf has lost the power to

ferment and if rolled and fired makes green tea. If leaf is heated to abount 140°F. it begins to turn red at the veins and mid rib in about 10 minutes, and after an hour or so it becomes completely red. At lower temperatures the time taken to redden is longer. The table below shows the effect of temperature on the rate of reddening of fresh tea leaf.

Temperature					
160°F.	leaf killed.				
140°F.	,,	begins to redden in about		10	minutes.
130°F.	,,	,,	,,	½	hour.
120°F.	,,	,,	,,	1	,,
115°F.	,,	,,	,,	3	hours.

Withered leaf turns red on heating in about two-thirds the time taken by fresh leaf. At air temperatures normally recorded during the Monsoon in Assam, averaging about 85°F., leaf may turn red towards the end of the withering period, although leaf if kept unwithered at such temperatures would not redden in less than 30 hours or more.

Ordinary fresh leaf plucked in the morning gives a pale yellowish solution when infused. If this leaf is withered in the cool, it still gives a pale yellow solution on infusion, not very different in colour from that given by fresh leaf. If the leaf is withered at temperatures about 90°F., however, reddish solutions may be obtained. Leaf plucked at the end of a hot afternoon gives distinctly red infusions even when fresh, suggesting that on the bush the leaf may form tannin "reds" if submitted to high temperatures.

The red infusions referred to are obtained from leaf which is undamaged. Very slight physical damage leads to the oxidation of tannin with a resultant red solution, but this colour is due to the presence of the oxidation products of tea tannin, and not to the "red" produced by condensation.

Red leaf.

Red leaf, either on account of tannin "red" or the condition which produces it, makes poor tea. Tea was manufactured from wholly red leaf and

although the process was modified in an attempt to reduce the effect of redness, the teas were described by tasters as "utterly undesirable" and "devoid of tea characteristics". Tea made from partially red leaf gives "thin," blackish liquors and dull coloured infused leaf.

Red leaf is often seen on withering racks in North East India and its avoidance is one of the problems of tea manufacture in the plains. Redness generally develops in the leaf basket and the temperature in the middle of a tightly packed basket may on occasion rise to 120°F. or even more. In a couple of hours such leaf is completely red and has lost a considerable amount of tannin. On infusion, a deep red solution is obtained.

Red leaf in the basket can be avoided, but red leaf formed on hot days in open withering houses is a more difficult problem and can only be avoided by shortening the time of wither. The leaf withered in a short time will make poorer tea than that withered for the full time at a normal temperature, but will be preferable to tea made from leaf withered at too high a temperature. In one experiment made at Tocklai, absolutely unwithered leaf gave a tea which was preferable to that made from leaf withered at a temperature of 100°F.

As a first approximation it may be stated that tea withered at temperatures above 90°F. will be poor. High temperatures do more harm at the end than at the beginning of the wither. This is one reason why leaf plucked in the morning and manufactured the next morning usually gives better tea than the afternoon's leaf, which finishes withering the next afternoon when temperatures reach a maximum.

3. The Practice of Withering.

On gardens where good quality teas are made it is usual for the pluckers to be supplied with small baskets which, as filled with leaf, are emptied into a larger basket kept in a convenient place in the cool. Every effort is made to keep the leaf lightly packed. The pluckings are collected (often by lorries) three or more times a day and quickly conveyed to the factory.

In Assam *chung* leaf houses are generally used whilst wire racks are used almost exclusively in the Dooars and the Surma Valley. The *chungs* are floors, usually made of bamboo covered with hessian, placed about 2½ feet apart.

Chung houses give a more even wither than racks. Leaf spread in a single layer on a wire rack withers so rapidly that the individual shoots dry unevenly. If the leaf is spread thickly, then the bulk dries unevenly. On a *chung* the rate of drying is reduced on account of the hessian and bamboo floor, with the result that leaf can be thinly spread and, in this manner, each shoot can dry slowly and evenly.

Chungs are also preferable to racks because they can be more evenly spread with leaf than the latter. In practice it is very common for the backs of the racks to remain unused and for the leaf to collect in a thick layer in the centre of the rack, often badly sagging. Even spreading is comparatively simple on a *chung*.

Another drawback to racks is that the buds and small leaves hang through the wire mesh and thereby overwither and blacken.

In erecting leaf houses attention must be paid to the prevailing breeze which should be met by the broad side of the house. Houses should not be more than about 50 feet wide, otherwise the leaf on the leeward side is liable to be underwithered.

When a series of leaf houses is built attention should be paid to the distance between them. On one garden in Assam a series of four houses has been built, one behind the other, with a distance of 100 ft. between each. On a certain day, the breeze to the windward side of the first house was blowing at 250 feet per minute (about 3 miles per hour, a common rate during Monsoon); behind this house the air movement was 210 feet per minute; behind the second house it was 200 feet, and behind the third, 190 feet. There was thus a very definite, but not serious, falling off in the strength of the air flow.

On another garden, three houses were built one behind the other at a distance of 35 feet apart. On a certain day the wind speed was 140 feet per minute to the windward of the first house, but only 15 feet behind it. Behind the third house the wind speed was 40 feet per minute. The reason for the last increase was the proximity of the main factory building which was in line with the third leaf house and deflected the general breeze towards this building.

It is difficult to draw very definite conclusions from the above observations since the wind speed was different in the two cases. It is clear, however, that leaf houses at a distance of 35 feet are too close for withering in the rains, although in the dry months, before the Monsoon, such spacing will give a slow withering house. It is preferable, however, to have some system of screens to slow up the wither if necessary, rather than to build leaf houses close together with this object.

Leaf should be spread on the racks or *chungs* at about 1 lb. to 9 square feet. In dry weather the spreading may be thicker and in wet weather somewhat thinner. With perfect spreading, leaf at the rate of 1 lb. to a square yard about completely covers the space. In practice, however, perfect spreading is not possible and often during wet spells, 12 or more square feet per pound of leaf are necessary.

In order to judge how much withering space should be erected, an estimate must be made of the average daily crop. It is uneconomic to cater for the very big days which occur a few times during the season. In Assam, where little tea is left unpruned, the average big day is about 1% of the total season's crop. In the Dooars, where often a third or half of the garden may be left unpruned, the crop is more evenly distributed and about ¾% of the total often represents the average big day.

In Assam, where a 10,000 maund crop is made, the average big day will be about 100 maunds tea or 400 maunds green leaf. This leaf spread at 9 square feet to 1 lb. will occupy $400 \times 80 \times 9 =$ 288,000 square feet. Thus for each maund (80 lbs.) of tea

made in the season about 28.8 or approximately 29 square feet of withering space will be required.

On gardens where the average big day is only be about ¾% of the total crop, 21.6 or approximately 22 square feet of withering space will be required for each maund of tea made in the season.

These figures must be taken as minimum requirements and are only sufficient if the leaf is not kept over more than 24 hours. If at the end of this time the leaf is still unwithered and fresh leaf is being brought in from the garden, then, ready or not, the racks have to be cleared to make room for the incoming leaf. A serious loss in quality may result and, on this account it is suggested that about 50% more space than the minimum recommended be put down.

Experiment goes to show that under rains conditions in North East India the best is made of the leaf if 100 lbs. dry at an even rate to about 65 lbs. in about 22 hours. These values refer to average temperatures of 83°F. *i.e.*, maximum and minimum, 88° and 78°F. respectively.

During hot spells these recommendations must be modified, and a less full wither in a shorter time will give the best results under the conditions pertaining. The tea made, however, will be inferior to that made from leaf withered more fully at lower temperatures. Very slow withering gives good teas, but the time is limited on account of the sourness of the leaf which often develops after about 30 hours.

4. Controlled Withering.

Withering is the most importance process in tea manufacture because it is the most difficult one to control. With some system of humidification and ventilation, ample space and machinery, efficient control is possible during rolling, fermentation and firing.

Controlled withering lofts have been used for many years in Ceylon and the Dooars. In Ceylon, the low temperatures re-

gistered in the up-country areas, combined with high humidities make natural withering, within a reasonable time, impossible on most days. In the Dooars, temperatures vary between 80° and 90°F. during the Monsoon, but high humidities make withering difficult.

In Ceylon the controlled loft has of recent years been developed to a high degree of efficiency, but in the Dooars this is not so in most cases. In order to control air movement, a loft must be air tight. This is never so in the ordinary Dooars loft, with the result that the suction air fans draw in air by the easiest route, which is usually from the adjacent space between wall and roof. It may be said that the air movement across the leaf in the average Dooars loft is practically negligible.

Another fault with the Dooars loft is the high temperatures registered therein. These result largely from the fact that the hot air from the drying room is allowed to enter the loft unmixed with outside air. In addition, corrugated iron roofs and walls add to the heat, so that the temperatures well over 100°F. are common in most lofts. The effect of such temperatures on the leaf is to produce "thin" teas with dull coloured infused leaf.

Similar remarks apply to the lofts in usé in the Surma Valley, although in this area the general practice is to wither in outside leaf houses.

Many attempts have been made to wither leaf by passing it through a Tea Drying Machine, using an air blast of 100° to 120°F., in about 20 minutes. Although leaf so treated takes on the fruity smell of naturally withered leaf and has actually lost moisture, the teas resulting from such leaf are usually "thin" and dull, showing the same characteristics as tea withered in a hot loft or tea made from red leaf.

Withering machines have been constructed on lines similar to Tea Drying Machines, but they have not been a success. In order that a withering machine shall be a reasonable size and shall turn out sufficient quantities of leaf, the drying must be rapid. This necessitates high temperatures or an air blast with

a reduced humidity. The second alternative has not been tried yet and it is doubtful whether it would be economically sound. In any case, rapid withering is incompatible with good quality teas, although withering machines may be of some use to dry the superficial moisture from leaf plucked on a wet day.

The construction of controlled lofts in Ceylon is along the following lines. A mixture of heated air and ordinary outside air is bulked in a central chamber to give an atmosphere with a certain temperature and humidity. The mixture is then drawn into the lofts situated on either side of the bulking chamber, and then across the leaf. In some cases booster fans are placed in the bulking chamber and the air is sent into the loft under pressure. In other cases the air is drawn into the loft by suction fans placed at the exhaust end of the loft. Both booster and exhaust fans, running in conjunction, are also used in some lofts.

It will be understood that when the warm, dry air first enters the loft its drying capacity is at a maximum. It follows, then, that the leaf near the bulking chamber will be dried more quickly than that at the exhaust end of the loft. In order to obviate this fault, reversible air flow systems have been introduced. By a simple arrangement of doors, air is made first to enter loft *A* from the bulking chamber and to pass through to loft *B*, thence to an exhaust. After some times the air flow is reversed and made to pass into loft *B* first, then through loft *A* to the exhaust. In this manner a more even wither is obtained than that given by a single loft.

Controlled lofts, built on Ceylon lines, have been erected in North East India but have not been a complete success. The chief reason for this is the high atmospheric temperature during the Monsoon period. In Ceylon the average air temperature in the highest tea districts is about 60°F. In the Kandy district the average is about 70°F. Such air can be warmed 10°F. or more and still be comparatively cool. In North East India the average air temperature is about 83°F. During the day the temperature rises to about 90°F, in which case the air is dry enough for a natural wither to be obtained. If the day tempera-

ture is as low as 80° to 82°F., as is common on a wet day, then the air is saturated. If such air is to be warmed to give it sufficient drying power to be of use in a loft about 100 feet in length, it must be heated to about 90°F. In order that air shall move throughout the length of the loft it must be sent through at a considerable speed, probably not less than 60 feet per minute. The combination of high temperatures and rapid air movement results in rapid drying and the uneven withering of individual shoots.

The air movement in lofts of the Ceylon type, reversible or otherwise, is irregular. Detailed surveys of such lofts show stagnant areas and draughty corridors with resultant irregular withering of the bulk of the leaf.

The objections to controlled lofts in North East India just detailed, are met by a two-storied Withering House at present being used experimentally at Sathkyah in the Dooars. Outside the House is a fan which sends air over a stove thence into ducts below the ground floor of the House. The warm air passes into the bottom floor by means of about 20 gratings, and enters as a warm draft at a temperature of 90° to 100°F. which mixes with the air already in the room. The temperature of the room atmosphere is thereby raised to about 85° or 90°F. No movement of air can be detected in the room, away from the gratings, by means of an anemometer and the only movement is a gentle upward convection current.

Warm air passes from the ground floor into the first loft by means of slots in the ceiling. Similarly further movement by convection takes warm air from the middle to the top loft. In the ceiling of this top loft are ducts fitted with fans which assist the upward air movement. Fans are also installed at various places in the walls of the ground floor and the lofts to carry off air which has passed over the leaf racks, and to reduce to a minimum the quantity of damp air passing from one loft to the next.

The air movement in the Sathkyah House is so slow that the leaf withers evenly and good teas result.

The capacity of the House is 75 mds. green leaf and the cost at site is about Rs. 60,000. The patents for the House are held by the Bateman Stalk Separator Co. Ltd.

The general concensus of opinion regarding controlled withering in the Brahmaputra Valley at present, is that natural conditions are usually sufficiently good not to warrant expenditure on controlled lofts. It is admitted that, on bad withering days, some form of control is desirable, but the Ceylon type of loft does not meet the case.

In the Dooars, weather conditions are much more unfavourable than in Assam. The rainfall is double that in the Brahmaputra Valley and the humidity in the Monsoon much higher. In this area some type of control is necessary during the greater part of the season.

The opinion is held in some quarters that the quality of Ceylon teas is largely the result of controlled withering and that if in Assam conditions were so controlled, our teas would equal in quality those of Ceylon. It is true that controlled withering is an important factor in the production of Ceylon quality, but fine leaf and general care in every branch of manufacture are also important factors. In addition, climatic conditions in Ceylon are conducive to quality. Reference to Stephens' Tea Share Manual will show that the gardens of Upper Assam produce teas equal in average value to the finest from Ceylon. Although controlled withering lofts for use on certain days of the season might still further improve prices, their installation might not be economical.

Gardens in Assam which are producing medium or inferior teas may improve quality by many means, all of which are simpler than the erection of controlled withering lofts and certainly more sure of success.

THE CLEANING OF FERMENTING ROOM FLOORS.

BY

S. F. Benton.

On careful consideration of the facts, one is forced to the conclusion that no definite evidence exists in favour of the theory that certain micro-organisms are necessary on the floor, in order to secure a correct fermentation of tea leaf.

The main fermentation process is controlled by the enzymes of the leaf, and is independent of outside biological influences. The cases which are made out from time to time in favour of old floors, as for instance the production of dull colours on a new floor, can be attributed to secondary factors—in this case the action of free lime in the new surface.

In the majority of factories, fermentation is conducted on a cement floor, sometimes in a doubtful state of repair, and coated with a layer of dried tea juice which varies from an infinitesimally thin film to a heavy deposit, an eighth of an inch in thickness. Such a floor becomes a breeding ground for micro-organisms of different types, and although these do not render the tea unfit for human consumption, their presence may have an adverse effect on the subsequent market valuation. The particular species present will determine the effect on the finished tea. Thus, one group produces taints. When this defect is noticed vigorous steps are usually taken to control the infection.

The results of infection.

There are, however, other types, the results of whose action are less obvious. Many varieties have the power of liberating ammonia from tea residues. In extreme cases a faint ammoniacal smell is observable in the fermenting room when these are present, and the production of ammonia in relatively large quantities is obvious under these circumstances. A deleterious effect on fermentation can occur, however, when ammonia formation is taking place to a lesser extent than this.

One of the desiderata in the fermentation of tea is an acid reaction in the juice expressed from the leaf during rolling, which influences the formation of the red tannin compounds. If micro-organisms on the floor are liberating ammonia, this, passing upwards through the fermenting tea will promote the development of an alkaline reaction in the juice, and the tannin compound formed under these conditions will be brown instead of red. The final result will be dull-colured infusions.

A third mode of action, which has only recently come under observation, is a direct attack by the micro-organisms on the tea tannin and total soluble solids during fermentation. Certain organisms have been isolated which are capable of destroying up to 50% of the water soluble tannin and 60% of the total soluble solids. If this type of action is permitted, soft and thin liquors are to be expected. The mechanism of the process is at present obscure.

From the earliest days of the Scientific Department the Manager has been advised to keep his fermenting floor clean but the methods recommended were based on an insufficient knowledge of the nature and activity of the micro-organisms present.

Sterilising methods.

The fact that tea is a food product of delicate flavour precludes the possibility of using strong disinfectants of the carbolic acid or poisonous metal type. An indirect method of control is therefore necessary, and for this purpose one must consider the factors which exhibit the greatest stimulating effect on the life of micro-organisms. These are :—

1. A relatively high temperature.
2. An adequate supply of moisture.
3. Food.

If one of these factors can be completely eliminated, life on the floor will be suppressed.

Under the present methods of tea manufacture, temperature and humidity are intimately connected, since a reduction in

temperature is brought about by introducing water into the air, which it cools by evaporation. It is necessary to keep the temperature as low as possible in the interests of fermentation, but in the plains during the greater part of the year, the lowest figure attainable by humidification is in the region of 80°F. Although admittedly better than the outside shade temperature of 90-95°F., this is still some 20° above the point at which micro-organisms become dormant, and since a temperature as low as 80°F. can only be obtained by an efficient system of humidification, a permanently damp floor results. The actual formation of pools of water on the floor can be avoided, and it is essential that this condition should be guarded against. Nevertheless the fact remains that a cool fermenting room has a damp floor, and, in most cases, a dry room is hot. Consequently a direct attack on the food supply is the only satisfactory method of control.

A floor which has been in use for some time is coated with a layer of dried tea juice which forms the food on which micro-organisms live. Of the various cleaning methods employed in the past, some made little or no attempt to remove this food supply, and others, although aiming at this requirement, failed since the reagents used were insufficiently vigorous in their action.

Previous methods of control.

The use of steam, scrubbing with water, or permanganate of potash were formerly considered the best methods of treatment. The progressive installation of the oil engine has placed steam out of reach of many gardens, and moreover, unless steam is used daily, it cannot be relied upon to maintain sterility when spore-forming organisms are present, since these survive the treatment and develop subsequently.

Permanganate of potash.

Scrubbing with water alone is of little use save as a temporary measure. The deposits of juice on the floor are insoluble in water, and unless these are removed, infection will be more or less permanent. A similar objection applies to the use of perman-

ganate of potash. This is an oxidising agent and as such has some destructive effect on organic matter. Its use as a sterilising agent has, however, proved inexpedient. As usually employed the solution has a bright pink colour, which represents a concentration of the order of one ounce per 100 gallons of water. Even when tested in a concentration a hundred times as great, incomplete destruction of the micro-organisms was recorded :—

Control	749,000,000 organisms per gram of scrapings	
5 minute treatment	192,000,000	,, ,,
30 minute treatment	160,000,000	,, ,,

A further objection to the use of permanganate of potash is that this reagent leaves a permanent brown stain on the floor and it is subsequently impossible to estimate the cleanliness of the latter.

A new sterilising agent was obviously required which should fulfil certain requirements. It should have a strong solvent action on organic matter and should be sufficiently powerful to destroy spore-forming organisms. It should be capable of use in relatively low concentrations and should either be free from objectionable odours or of such a constitution that the odour would be neutralised by the tea or driven off in firing. Finally it should be cheap and readily obtainable. Such a reagent has been found in Electrolytic Chlorine, or "E.C."

Electrolytic Chlorine.

E.C. is produced by passing an electric current through a solution of common salt. Chlorine gas is formed at the positive pole and Sodium at the negative, where it reacts with water to form caustic soda, with the evolution of hydrogen. The electrodes are so designed that the chlorine and caustic soda are brought into intimate contact, and these combine to form sodium hypochlorite—the reactive substance in the finished product. Since the chlorine and caustic soda are formed in molecular proportions, there is only the slightest trace of free alkali when the process is complete. This renders the reagent eminently suitable for tea factory work, where strong alkalis are undesirable on account of their effect on

fermentation (*vide* above—the production of brown tannin bodies).

Efficiency of E. C.

When used in a cold solution at a concentration of one ounce per gallon of water, E. C. will destroy non-sporing organisms in five minutes. Spores are not killed by cold solutions, but if the above solution is used at a temperature above 60°C. (140°F.) a five-minute treatment will eliminate both spores and vegetative cells.

The action of E.C. on organic matter is extremely rapid, particularly when a hot solution is employed. If the reagent is added to a suspension of "sludge" from a dirty floor, in water at 80°C. (176°F.), the solution is completely cleared within thirty seconds, provided that the amount of E.C. is sufficient to destroy the whole of the organic matter in the solution.

The chemistry of the reaction is somewhat complex and will not be dealt with in this article. It will suffice to state that the available chlorine is itself neutralised by the organic matter during the decomposition of the latter. A given amount of E.C. can therefore only destroy an equivalent amount of dirt on the floor.

Limitation of E. C.

The ratio of E.C. to tea residues has been determined experimentally. One pint of E. C. full strength will destroy 6.48 grams of organic matter. When diluted for use, this amount of E. C. will yield ten gallons of cleaning solution, will cover an area of approximately 50 ft. × 40 ft. and will consequently oxidise approximately 3 milligrams of tea residues per square foot. A normally neglected floor may be expected to carry up to 5 grams of residues per square foot, and it is thus obvious that the mere flooding of a floor with E.C. solution will only remove a very small percentage of the surface dirt. To clean a floor completely in this manner would require a large expenditure on E.C., and would be uneconomical. If the process were not carried to completion, the results would be of a temporary nature, and it would be necessary to flood the floor daily before manufacture commenced, in order to destroy the

organisms which had grown overnight. More satisfactory methods have therefore been developed.

Method of use.

As stated above, E.C. should be used in a hot solution. A word of caution is necessary on this subject. If the solution is heated after the addition of the reagent, the oxidising power will be destroyed. On the other hand, E.C. may be added to water previously heated almost to boiling point without any serious loss of efficiency.

In dealing with floors which have only a moderate deposit of tea juice on their surface, and for routine cleaning operations, which should be conducted weekly if not more frequently, the following method has proved satisfactory in practise. Water is heated to at least 140°F. and E.C. added at the rate of two ounces per gallon. This amount may be increased if desired. The solution should be applied with brushes as soon as possible after preparation. If the deposits are old and tough, a wire brush may be necessary, but for floors in better condition the ordinary English pattern scrubbing brush gives the best results. Short bristles are preferable to long, as a length greater than two inches endows the brush with a springiness which effectively prevents the bristles from penetrating the dirt. The total solvent action of E.C. itself is small but the use of a suitable brush carries the solution through to the surface of the cement, and detaches the deposits from the bottom, with a minimum expenditure of E.C.

The brushes should be dipped frequently in the cleaning solution, and the floor scrubbed foot by foot. This work requires proper supervision, since the natural tendency of the worker prompts him to cover the maximum possible area in the minimum of time, the benefit arising from work of this type being speedily nullified by the redevelopment of micro-organisms on the residues which have been left behind.

When floors are very heavily coated with dried tea juice E.C. treatment should be preceeded by scraping. To facilitate removal of the thicker deposits the floor may be flooded with hot E.C. solution until the required degree of softening has taken

place, and the organic matter can be scraped away with a blunt knife. Final treatment is as outlined above. Floors are sometime found where the surface layer of the cement is soft, crumbly, porous and badly pitted, due to the use of a low grade cement, an excess of sand in the mixture, or frequently, to an excess of water which has "drowned" the cement as a result of overworking the mixture while setting is taking place. In cases of this nature it is best to re-surface the floor with pure cement, since a porous surface breeds micro-organisms in the spaces between the particles, and treatment is extremely difficult, if not impossible.

Close attention should of course be paid to the drains and the bases of pillars in the fermenting room, the former in particular when these lie in between raised beds. Such drains are frequently kept in an unclean condition, leaf falling into them during spreading operations becomes infected and, if replaced, contributes its quota of micro-organisms to the leaf on the fermenting beds.

Chlorogen.

In addition to E.C. two other forms of hypochlorite are available. One—a sodium hypochlorite, sold under the name of chlorogen, and the other a calcium salt, prepared by churning bleaching powder with water. Chlorogen is manufactured by passing chlorine gas into caustic soda solution, and as an excess of the latter is always present, the solution has a strongly alkaline reaction. If used in conjunction with a thorough cleaning of the floor, no bad effects should occur, provided the floor be thoroughly washed after treatment. Complaints have, however, been received that its use has been followed by dull colours in the infused leaf. It is tentatively suggested that the alkali has been absorbed by deposits on the floor, and a slow evolution of ammonia has resulted in such cases. The same objection applies to the use of the bleaching powder product, with the further complication of the calcium forming insoluble precipitates of calcium tannate on the floor.

Electrolytic chlorine is recommended in preference to either of these reagents.

THE ACIDITY OF TEA SOILS OF NORTH EAST INDIA.

Part I.

BY

C. J. HARRISON.

One of the most useful determinations in the analysis of soils, especially in regard to judging their suitability for tea is that of soil acidity. It is well known that the tea plant can exist on a soil of any acidity from very acid to neutral or slightly alkaline, but the range of acidity over which tea grows best is much more confined, and it has often been found that though a soil may be sufficiently acid to grow tea giving up to about 6 mds. per acre, it is practicably impossible to increase the yielding capacity of the bushes unless the acidity of the soil is increased by suitable manuring.

The meaning of acidity.

It is necessary to a proper understanding of the question, to have a rough idea of what is meant by acidity and by the various terms employed. (1).

Pure water is neither acid nor alkaline, but neutral. It is composed of molecules of hydrogen and oxygen combined together in the ratio of two parts by volume of the former gas to one of the latter. These molecules are not entirely stable but are continually splitting up momentarily into two parts, one of hydrogen and the other of equal parts of hydrogen and oxygen, and reforming again. This is represented by the equation.

$$H_2O \rightleftarrows H^{\cdot} + (OH)^{\cdot}$$

The split up portions of the H_2O molecule are called hydrogen and hydroxyl "ions" respectively, and are unstable and cannot be isolated. The dot in conjunction with the symbol H or OH indicates the ionic nature. The hydrogen ion carries a positive electric change, while the hydroxyl ion carries a negative charge.

In absolutely pure water only a very small percentage of the molecules are split up, or dissociated at any given instant. A

measure of this dissociation is the concentration of the hydrogen ions, which in the case of pure water is $\frac{1}{10,000,000}$ or 10^{-7}.

In the case of an acid such as hydrochloric or nitric acid practically all the molecules are dissociated into ions. Thus for hydrochloric acid

$$HCl \rightleftarrows H^{\cdot} + Cl^{\cdot}$$

Therefore by mixing a certain amount of acid with a certain volume of water, we can get solutions with definite and known hydrogen ion concentrations. By mixing 36.5 grams of pure hydrochloric acid with one litre of pure water, we get a solution whose hydrogen ion concentration is I. A solution one-tenth of this strength has a hydrogen ion concentration of one-tenth (or 10^{-1}) and so on till with extremely weak solutions, having very small hydrogen ion concentrations, we approach that of water (10^{-7}). Thus a solution of hydrogen ion concentration $\frac{1}{1,000}$ (or 10^{-3}) is more acid than one of $\frac{1}{100,000}$ (or 10^{-5}). A convenient method of indicating the acidity is to take the index figure of the hydrogen ion concentration, ignoring the negative sign. This value is called the pH value. Thus the pH of pure water would be 7, which is neutrality. The smaller the pH value, the more acid is the solution. Thus a solution of pH 5 is more acid than one of pH6 and less acid than of pH4.

In alkaline (or basid) solutions, the hydrogen ion concentration becomes smaller and smaller and the hydroxyl ion concentration larger and larger as the alkalinity increases, so that the pH becomes bigger and bigger. Thus a solution of pH 10 is more alkaline, (or less acid) than one of pH 8.

Soils in general vary from about pH 3 (most acid) to about pH 9 (most alkaline), though with tea soils in North East India the range is generally from about pH 4 to about pH 7.5. In the case of tea the best results are obtained in soils varying from pH 4.5 to pH 6.0 (2), though certain exceptions do occur and will be referred to later.

Theories of Soil acidity (3).

The presence of free mineral acid (*e.g.* sulphuric or hydrochloric acids) in soils has long been discredited, but the occurrence of organic acids derived from the decay of vegetable matter can be definitely proved and in highly organic soils such as *bheels* and peats, soil acidity may be due, in part at any rate, to such substances.

In mineral soils comparatively low in organic matter however, acidity may be much greater than in peaty soils and the source of this acidity must be sought elsewhere. Recent work has shown the importance of the clay fraction in controlling acidity. The colloidal particles may be regarded as comprising a complex acid which contains aluminium and silica, and can be considered as a complex aluminosilicic acid.

H (Al Si. complex).

When lime (calcium carbonate) is added to the soil, the hydrogen ion of the clay acid is replaced and a calcium clay salt formed.

When a neutral salt like nitrate of potash is added to a soil, a potash clay salt is formed and free nitric acid liberated. This free nitric acid liberates aluminium from the clay and in the neutral salt extract we have soluble aluminium, and an acid reaction due to the nitric acid.

It is found that if we add lime to a stiff clay soil, the clay becomes "deflocculated" and the soil becomes less stiff. If however nitrate of soda or a similar sodium salt is added, the soil becomes extremely sticky and tilth is lost. Potash however does not produce a very sticky soil, as does soda. The reason may well lie in the different physical properties of the different clay salts formed.

Thus,

H. (Al. Si. complex) is normal stiff clay.
Ca (Al. Si. complex) is not sticky.
Na (Al. Si. complex) is extremely sticky.
K (Al. Si. complex) is much less sticky.

It is now easy to see that a soil giving a neutral or almost neutral soil solution may have a "reserve" acidity, which is brought into play by extracting with neutral salts. The clay acid being insoluble does not appear in the clear soil solution, which when boiled to remove acidity due merely to dissolved carbon dioxide, is generally about neutral. By extracting the soil with neutral salt solution *e.g.*, nitrate of potash, we have

Potassium nitrate + H. (Al. Si. complex) = Potassium (Al. Si. complex) + nitric acid ($H.NO_3$).

We can continue to extract an apparently neutral soil with nitrate of potash solution, and still obtain an acid extract, until all the hydrogen of the soil acid has been replaced by potash.

Now on soils which have been made neutral by liming all the clay acid has been neutralised by the lime and the hydrogen replaced by calcium. By extracting such a soil with nitrate of potash solution no free nitric acid can be developed and the extract will be neutral. If more than sufficient lime has been added to neutralise the soil, there will be solid lime in the soil and this comes into solution in the nitrate of potash extract, rendering this alkaline, or at any rate, less acid than the soil water solution. Examples of the results obtained on soils which have been excessively limed are given later in the article.

Methods of determining the acidity of soils.

(1) *Lime requirement of the soil.* In early work on soils a measure of the acidity was sought in the amount of lime required to bring a soil to neutrality (3). This was determined by shaking a certain weight of the soil with a known amount of bicarbonate of lime and estimating the excess lime which has not been neutralised by the acid in the soil.

Though the method gave very useful results it has not been found satisfactory in the case of soils in North East India and a better method,—one which is used now with certain modifications —is the "Hopkins" method. This method as now used is as follows :—100 grams of soil are shaken up with 250 cc. of neutral

potassium nitrate solution of a certain strength (normal). After 3 hours the liquid is filtered off from the soil and the acidity estimated by finding the amount of alkali of a certain strength required to bring it to neutral point. From this value, a figure representing the pounds of lime required to neutralise one million pounds of soil, is calculated. This figure is called the Hopkins acidity of the soil.

It is found, however, that if we add the required amount of lime indicated by the Hopkins acidity figure to a particular soil, the result is seldom, in fact scarcely ever, to produce a neutral soil, and in practice anything up to 4 times the amount of lime as indicated by the Hopkins acidity, may be necessary to effect neutralisation.

The figure has, however, been of great value in determining the degree of acidity of a soil, provided the results are carefully interpreted.

In general, tea grows successfully on soils showing a wide range of acidity, the Hopkins figure depending on the type of soil under consideration.

For a Mal sand (Dooars) the value is generally round about 60-160; for a mid Assam sandy loam about 300, for an Upper Assam soil about 500; for a stiff Red Bank (Dooars) soil or a sandy *teela* (Sylhet) soil about 800; and for a peat *bheel* 2,000 or 3,000. Thus a value of about 300, which would be very high for a Mal sand, would be very much too low to grow good tea on a *bheel* soil and would indicate that the *bheel* had come under the influence of lime or similar alkaline substance.

There have been many cases however, where the Hopkins acidity has given misleading results, as for example indicating soils on which excellent tea is growing, as being round about neutral point and therefore apparently unsuitable for tea.

It has been necessary, therefore, to obtain further information regarding the acidity of soils and two other methods which

measure directly the pH of the soil have been developed and used successfully.

(2) *Electrometric pH.* The acidity of a soil is a function of its hydrogen ion concentration and since these ions carry a charge of positive electricity, the sum effect of the hydrogen ions in the soil water is an electric potential which can be measured accurately and which is directly proportional to the pH of the soil. The method used is a somewhat complicated one requiring expensive apparatus, and has not been completely worked out for field conditions, but gives very accurate results for the great majority of soils. So far it has been used in the laboratory for checking figures obtained by the colorimetric method, and for purely research purposes.

(3) *The colorimetric pH.* The method in use for routine purposes is the colorimetric one (3) which will be described in more detail. It depends on the fact that the colours of certain chemical dyes depend on the acidity of the solution to which they are added. It is well known that blue litmus paper placed in acid solution turns red, while red litmus becomes blue if placed in alkali. In a neutral solution, either blue or red litmus maintains a purplish red colour, *i.e.* mid-way between blue and red. Litmus has been used for testing the acidity of a soil, but since soils with a pH of round about 6.5 will turn blue litmus red, and since such soils may be unsuitable for tea on account of their low acidity, the litmus test for soil acidity may be very misleading.

Out of a large number of dyes, about half a dozen have been selected on account of their reliability and brilliance of colour, as being suitable for use in determining the degree of acidity of solutions. To take one dye,—methyl red for example—in a solution of pH 4.2 its colour is red. As the solution becomes less acid, the red colour changes to orange, and finally at pH 6.3 is yellow. This range (pH 4.2 to 6.3) embracing the colour change of methyl red is known as its *virage*. By a suitable choice of dyes we can cover the whole pH range for soils, *i.e.*, from about pH 3 to pH 8. The following is a list of dyes, or indicators

together with their *virages* and colour changes, suitable for use in soil acidity determinations.

Indicator.	pH *virage*	Colour change.
Brom phenol blue (B. P. B.) ...	3 0—4 6	yellow to blue
Methyl red (M. R.) ...	4·2—6·3	red to yellow
Brom cresol purple (B. C. P.) ...	5·2—6·8	yellow to purple
Brom thymol blue (B. T. B.) ...	6 0—7·6	yellow to blue
Phenol red (P. R.) ...	6·8—8·4	yellow to red.

It will be seen that the total *virage* of the five indicators completely covers the pH range required in estimating the soil's acidity and moreover, each *virage* overlaps the next over a certain range so that in many cases the acidity can be determined independently by the two indicators.

It is necessary first to prepare a series of solutions of different known acidities, to which the various dyes are added, thus giving sets of standards with which to compare solutions whose acidities are required. Thus having added an indicator to a solution of unknown acidity the colour produced is compared with the standards for the particular indicator used, until a match in colour between a standard and the unknown is obtained. The pH of the solution to be tested is then known. For soil work it is usual to prepare 5 sets of standards, one set for each indicator, for pH values 3.2, 3.4 etc., up to about 8.4. It is possible to match colours to an accuracy of pH 0.1. Thus the method is considerably less accurate than the electrometric method by which an accuracy of pH 0.02 can be reached, though for most purposes the degree of accuracy obtained by the former method is quite sufficient.

The method in use for determining the pH of soils colorimetrically is as follows. Fifteen grams of the soil sample after air drying and sampling are shaken up in a clean flask with 45 cc. of neutral water and the suspension left for 24 hours. The slightly cloudy soil solution is carefully poured off into three test tubes, 10 cc. in each tube.

To one of the tubes 15 drops of appropriate indicator solution of a certain strength is added and the tube gently shaken. The 3 tubes are then placed in a comparator. This is a wooden box with 6 holes in the top and three parallel slits in the front and back. The tubes, together with appropriate standards are examined by holding the comparator up to the light, or against a white background, and the colour of the soil solution and indicator matched against the standards.

The arrangement of the tubes is such that the two tubes containing standards are backed by the two tubes of soil solution, and the tube containing soil solution and indicator, is backed by a tube of water. By this arrangement the depth and composition of the three sets of colours is the same. This eliminates the disturbing effect of cloudiness due to colloidal clay in the soil solution, on the colour of the indicator.

It has previously been stated that the soil acidity may be due mainly to the colloidal clay fraction, composed mainly of complex aluminosilicic acids. If a soil containing clay is shaken up with nitrate of potash, the solution will generally be found to be round about pH 4, that is, much more acid than a water solution of the soil. Here, the potash has displaced the hydrogen from the clay complex and the resulting nitric acid solution dissolves out some of the alumina in the clay. With certain soils, however, the hydrogen in the clay fraction has already been displaced by liming, and on shaking such soils up with nitrate of potash little or no acidity is developed, so that the pH of the nitrate of potash extract will be about the same as that of the soil water solution. Such soils rarely grow tea successfully and it will be realised that pH of the nitrate of potash solution is as informative as that of the water solution.

Thus, taking the following results on two soils :—

	pH of water solution.	pH of nitrate of potash solution.
A.	6·6	5·0
B.	6·6	6·6

Soil A as far as acidity is concerned might grow tea successfully, whereas soil B, with no reserve acidity would not, although the actual soil water pH is the same in both cases.

The use of acidity determinations.

A very important use to which these determinations have been put is the testing of soils on which it is proposed to plant tea. Though generally the virgin soils in North East India are sufficiently acid for tea, cases occur in which the land has been flooded by a river which earlier in its course has passed through limestone or similar alkaline deposit. The gradual deposition of alkali carried down in solution by the river, on a soil which originally may have been acid, may in the course of time neutralise the soil completely and render it unfit for tea. This change may occur in a comparatively confined strip of land over which the river has flowed, and there is often nothing to distinguish the alkaline soil from adjoining acid soil. The difference shows up however when tea is put out.

In the Dooars there are several wide strips of land which have been rendered alkaline from flooding by "alkaline" rivers, and where tea has been planted in ignorance of the alkaline nature of the soil, results have seldom been successful.

An example of the effect of this reduction in acidity of the soil on the growth of tea is given by the following figures from the Dalgaon district in the Dooars containing patches of alkaline soil.

		Hopkins' acidity.	Soil solution pH.	pH of KNO_3 extract.
1.	Fairly good tea	292	5·8	4·5
	Poor tea	43	6·0	5·3
2.	Fairly good tea ...	43	5·8	5·3
	Poor tea	7	6·2	5·9
3.	Infertile	neutral	6·1	6·9
	Fertile	63	5·6	4·8

From two samples of soil from another Dooars district the following figures were obtained :—

	Hopkins acidity.	Soil solution pH.	pH of KNO_3 extract
Fertile soil	21	5·8	5·4
Infertile soil	alkaline	6·9	7·4

Where small isolated patches of alkaline soils or low acidity soils occur, these may have been old *busti* (village) sites, or may have been the sites of lime or brick kilns, etc. Such patches are common in tea gardens and where planted with tea show up badly against tea on normal adjoining soil. The following figures indicate that at least one of the reasons for *busti* patches growing bad tea is to be sought in the soil acidity.

District.	Soil.	Hopkins acidity.	pH of Soil solution	pH of KNO_3 extract.
Nowgong ...	busti patch bad tea ...	21	6·0	4·7
	good tea adjoining ...	568	5·5	3·9
	bad patch ...	alkaline	7·2	7·2
	,, ,, ...	7	6·0	6·2
	good tea ...	249	5·8	4·5
	,, ,, ...	114	5·8	4·7
Dunsiri ...	bad tea No. 8 low ...	27	5·8	4·6
	good tea No. 8 high ...	294	5·4	4·4
Lakhipur district Cachar	No. 6 C. E. S. Good ...	3378	5·2	3·9
	,, C. E. M. Poor ..	neutral	6·4	6·2

The effect of Fertilisers on Soil Aridity.

(1) *Lime.* The effect of addition of lime to an acid soil has been studied at Tocklai both in the laboratory and in the field(2). Results show that when lime is added to an acid soil, the reduction in acidity which is great at first, becomes less as neutrality is approached.

Thus in the case of soil taken from plots at Tocklai the following figures were obtained :—

lbs. lime added per acre.	Hopkins acidity.	pH colorimetric		pH electrometric	
		of soil solution.	of nitrate of potash solution.	of soil mud.	of nitrate of potash solution.
nil.	452	4·6	4·2	4·51	4·24
750	169	5·1	4·8	4·98	4·34
1500	49	5·3	5·3	5·34	5·60
3000	4	5·9	6·9	6.00	7·05
4500	0	6·4	7·0	6·55	7·07
6000	0	6·7	7·3	7·02	7·25
7500	0	7·0	7·4	7·30	7·40

In each case 200 grams of dry soil was taken, and varying quantities of limestone were added equivalent to the amounts of lime per acre given in the first column. In the second column, the Hopkins acidity figures indicate theoretically the pounds of quick lime necessary to add to one million pounds of the soil to neutralise it *i.e.*, to bring its pH to 7.0. That is, since the top 9 inches of one acre of dry soil weigh about three million pounds, the original soil required theoretically 1,356 lbs. per acre of quick lime to neutralise it, or about twice that amount of limestone *i.e.*, about 2,700 lbs. of limestone. This does not agree with the figures actually obtained, as more than twice this amount had to be added to make the soil nearly neutral.

Agreement between colorimetric and electrometric pH values is fairly close until neutrality is approached. This is due to the fact that in the colorimetric estimation, a soil : water ratio of 1 :3 is used, whereas the electrometric reading is taken on a soil : water ratio of 7 :5, the electrode being dipped in the mud. The 1 :3 soil solution is only slightly buffered, that is its acidity is readily changed by disturbing influences such as introduction of substances of a different acidity into the solution. Carbon dioxide from the air is absorbed, and tends to lower the acidity of soil solutions with pH about neutrality. In the case of

the 7 : 5 ratio soil mud, this is much more highly buffered and resists the influence of carbon dioxide.

Experiments on liming of soils in the field have been done at Tocklai and on the Betjan plots at Borbhetta. In the Tocklai experiment a piece of land was divided into 9 plots and treated according to the following scheme.

1. left untreated.
2. 400 lbs. limestone per acre added.
3. 800 ,, ,, ,, ,, ,,
4. 1200 ,, ,, ,, ,, ,,
5. 1600 ,, ,, ,, ,, ,,
6. 2400 ,, ,, ,, ,, ,,
7. 3200 ,, ,, ,, ,, ,,
8. 800 lbs. quicklime ,, ,, ,,
9. 1600 ,, ,, ,, ,, ,,

In August 1924 half of each plot was treated with sulphur- in quantity about sufficient to neutralise the original lime added, that is one third of the weight of lime stone. This theoretically should bring the soil acidity back to its original value.

Estimations of Hopkins acidity, pH of soil extract and KNO_3 extract were made at intervals both on neutralised and unneutralised plots. The first acidity determinations were done in February 1924, before sulphuring, and in addition the soluble alumina in the nitrate of potash extract was determined. The results are as follows.

Plot No.	$CaCO_3$ per acre, maunds.	Hopkins acidity.			Alumina %
		February 1924	April 1924	July 1924	
1.	nil	503	488	307	·012
2.	50	38	39	21	traces.
3.	100	21	14	7	
4.	150	17	11	4	
5.	200	7	0	0	
6.	300	14	4	4	*nil.*
7.	400	alkaline	neutral	0	
8.	100 mds. CaO	14	7	4	
9.	200 ,, ,,	alkaline	alkaline	alkaline	

The following estimations were made, after sulphur had been applied to the half-plots, in August 1924.

Plot No.	$CaCO_3$ per acre, maunds.	Hopkins acidity.		% alumina in sulphured plots.
		limed.	sulphured.	
5.	200	alkaline	959	0·18%
6.	300	neutral	7770	0·24%
7.	400	4	5950	0·31%

It is interesting to note that the lime had rendered the soil alumina completely insoluble to the nitrate of potash solution, but after the acidity of the soil had been more than restored by addition of sulphur, the soluble alumina again appeared in the soil and in greater amount than before liming. The percentage of soluble alumina is thus in some measure an indication of the degree of soil acidity.

Further determinations of acidity were made in May 1928 and August 1930.

$CaCo_3$	Unsulphured.						Sulphured.					
	Hopkins Acidity.		pH KNO_3 ext.		pH direct.		Hopkins. Acidity.		pH KNO_3 ext.		pH direct.	
	5/28	8/30	5/28	8/30	5/28	8/30	5/28	8/30	5/28	8/30	5/28	8/30
1. nil ...	518	316	4·0	4·3	5·4	...	...	...	...	...	...	...
2. 50 mds.	63	85	5·0	4·8	5·8	5·75	861	685	3·8	4·1	4·2	5·0
3. 100 „	28	10	5·4	5·8	6·0	6·15	1085	713	3·7	4·1	4·4	4·8
4. 150 „	10	4	6·2	6·75	6·1	6·2	826	889	3·7	3·95	3·9	4·8
5. 200 „	7	7	6·4	6·7	6·2	6·05	868	812	3·4	3·6	3·55	4·6
6. 300 „	7	4	6·5	6·8	6·7	6·4	1148	826	3·4	3·7	3·6	4·6
7. 400 „	0	0	7·0	7·05	7·2	7·0	833	692	3·7	4·0	4·0	4·85
8. 100 CaO.	10	4	6·0	6·7	6·1	...	980	1137	3·6	3·7	3·8	4·2
9. 200 „	7	4	6·4	6·7	6·0	...	777	1044	3·5	3·7	3·8	4·8

In every case the sulphur addition has reduced the acidity to a greater extent than equivalent quantities of lime increased it and now the acidity on the sulphured plots is well above the original figure for the untreated soil.

On the Betjan plots at Borbhetta, lime was added in varying quantities in 1922. Acidity determinations of the various plots have been carried out several times since the liming.

The results are given below :—

Series.	Treatment.	Hopkins Acidity.			pH of Soil.			pH of KNO_3 Extract.			Total Crop 1922—1929.
		1924	1927	1929	1924	1927	1929	1924	1927	1929	
											Mds.
1	No lime, no manure	564	438	346	5·1	5·65	5·45	4·4	4·55	4·55	86·2
3	No lime, manured	455	424	279	5·2	5·6	5·5	4·3	4·6	4·6	99·3
2	15 mds. limestone no manure ...	200	210	149	5·3	5·85	5·65	4·4	4·8	5·2	79·4
4	15 mds. limestone ... ... A ...	166	207	214	5·4	5·85	5·6	4·4	4·65	4·7	
8	manured ... ... B ...	134	207	125	5·5	5·85	5·6	4·5	4·7	4·9	
11	15 mds. limestone in 2 doses, manured ...	85	225	125	5·5	5·8	5·65	4·7	4·8	4·8	
5	12½ mds. slaked lime ... A ...	280	308	210	5·4	5·7	5·6	4·3	4·7	4·7	100·4
9	manured ... B ...	258	265	112	5·3	5·75	5·6	4·3	4·7	5·0	
10	12½ mds. slaked lime in 2 doses, manured...	111	279	178	5·5	5·7	5·6	4·4	4·65	4·8	
7	30 mds. limestone, manured	32	139	50	5·7	5·95	5·75	4·6	4·9	5·3	
12	30 mds. limestone in 3 doses, manured ...	4	30	28	6·0	5·95	5·8	5·1	5·75	5·56	98·8
6	25 mds. slaked lime, manured ...	111	241	85	5·5	5·75	5·7	4·4	4·6	5·05	
13	80 mds. limestone, manured	3	8	6	6·6	6·1	6·1	6·6	6·6	6·4	93·9

Comparison of series 1 and series 2 shows the depressing effect of lime on crop, when no other manures are applied.

The manuring rotation included two years of green cropping, and since the limed plots grew bigger green crops, these plots received additional manure from this source, and on plots where a comparatively small amount of lime was used its depressing effect on the crop was more than compensated for by the increase from the manurial effect of the extra weight of green crop.

More lime than was sufficient to grow an average good green crop resulted in a nett decrease in crop.

On soils, such as those at Borbhetta, where high acidity results in poor growth of leguminous green crops, the use of lime in small quantities undoubtedly pays. Generally basic phosphates which are used in conjunction with a green crop, supply sufficient lime to enable the green crop to grow successfully, so that it is seldom necessary to apply lime itself.

2. *Sulphur.* Soils which have too low an acidity to grow tea well may be made more acid by the addition of sulphur, which after oxidation to sulphuric acid, combines with the basic substances like lime thus removing the calcium ion from the clay acid as calcium sulphate, and restoring the hydrogen ion. Owing to the high cost of sulphur its use is practicable only on soils which are not too alkaline, and where the area to be treated is not too large.

The effect of addition of sulphur to different types of soil is being studied in the laboratory and in the field. The following two examples of the effect of sulphur added in different quantities to soil illustrate what happens.

A soil with Hopkins acidity of 207 and pH of 5.7 was treated with varying quantities of sulphur and left for 15 days in the

laboratory with 20% moisture content. The acidities of the samples at the end of the fortnight were as follows :—

grams sulphur per 100 grams soil.	lbs. suldhur per acre.	Hopkins acidity.	pH of soil solution.	pH of KNO_3 extract.
nil	*nil*	207	5·7	4·6
·025	750	409	4·2	4·4
· 05	1500	1059	3·6	4·1
· 10	3000	1800	3·4	3·9
· 13	3900	2598	3·2	3·7
· 20	6000	3142	3·0	3·4

On a soil which is not very low in acidity, such as the one on which the above test was made, the effect of sulphur in reducing acidity is rapid, and great. With soils containing more lime, and those nearer the neutral point, the effect of the same quantities of sulphur would be expected to be much smaller.

A sample of stiff neutral soil was weighed into 6 lots and treated with varying quantities of sulphur, each lot being made up to 20% moisture. After 30 days the samples were tested for acidity with the following results.

gms. sulphur per 100 gm. soil	Sulphur in lbs. per acre added.	Hopkins acidity.	pH of soil solution.	pH of KNO_3 extract.
nil	*nil*	4	6·4	6·8
·015	450	18	5·9	6·9
·025	750	18	5·8	6·9
· 05	1500	18	5·3	6.8
· 10	3000	35	4·9	5·6
· 13	3900	71	4·6	5·0
· 20	6000	212	4·35	4·6

It is interesting to note that, as with the much more acid soil treated with sulphur, the pH of the soil solution is reduced to a far greater extent than is the pH of the potassium nitrate extract.

Before making recommendations for correcting low acidity by additions of sulphur it is necessary at present to make laboratory tests similar to the above, since different soils react

differently to any given amount of sulphur. On a garden in the Dooars with a soil of the Mal Sand type, plots were treated with different quantities of sulphur in three equal doses, each dose applied at one year interval. One plot was similarly treated with three equal doses of sulphate of ammonia. The results were as follows :—

Acidity of soils after Sulphur treatment.

Treatment Total dose for three years.	Hopkins acidity.		pH of soil solution		pH of KNO_3 extract.	
	11-7-29.	22-7-30.	11-7-29.	22-7-30.	11-7-29.	22.7-30.
1. 60 mds. Sulphur...	2,828	2,718	3·2	3·2	3·4	3·1
2. 30 „ „ ...	2,559	2,753	3·7	3·2	3·4	3·1
3. 15 „ „ ...	1,436	2,259	4·2	3·6	3 6	3·4
4. 6 „ Ammonium sulphate	22	124	5·8	5·0	5·2	4·4
5. *nil*	22	alkaline	6·2	7·5	5·3	7·1

It will be seen that comparatively small addition of sulphur (3 doses of 5 mds. per dose) have effected a big change in acidity while larger doses have reduced the acidity below that tolerated by tea and on the heavily treated plots the tea is rapidly dying out. Another important point is that, even a year after completion of the sulphur applications, there is still further reduction in acidity on both the sulphur treated plots and those treated with sulphate of ammonia.

3. *Nitrogenous and organic manures.* Sulphate of ammonia has a definite effect in increasing the soil acidity, while calcium cyanamide has the opposite effect. Nitrate of soda has little or no immediate effect, but, since the sodium combines with the clay acid, the final result is a decrease in acidity. Organic manures in large quantity increase the colloidal humus fraction in the soil and would be expected slightly to increase the acidity temporarily, though the residue of ash of basic nature left in the soil should finally cause a reduction in acidity.

The following acidity determinations were made on soils treated with different nitrogenous manures, at Borbhetta.

Manure.	Hopkins Acidity.	pH of soil solution.	pH of KNO_3 extract.
Nil ...	497	5·7	4·1
Ammonium Sulphate ...	674	5·2	4·0
Sodium nitrate ...	488	5·95	4·15
Nervox (animal skin and sinew)	434	5·6	4·3
Oilcake	427	5·7	4·2
Green manure ...	429	5·7	4·2
Nil	203	5·8	4·6
Calcium cyanamide ...	173	5·8	4·8
Fish Guano	268	5·8	4·5
Animal meal	264	5·5	4·6

In the first series, the plots had been manured annually for 7 years with the manures detailed above, in quantities to supply 30 lbs. nitrogen per acre per annum. In the latter series, a similar quantity of nitrogen had been applied for 4 years. The effect of the sulphate of ammonia in decreasing acidity is marked, while in the case of nitrate of soda the acidity is slightly decreased. Oganic manures have had no appreciable effect on the acidity.

The effect of calcium cyanamide was not very marked when these determinations were made, nor had the tea been affected by the very slight lowering in acidity. It is expected that with a few years more of continuous manuring with calcium cyanamide the soil acidity will be markedly decreased, with a resultant adverse effect on the tea.

4. *Phosphates.* Phosphatic manures decrease the acidity of soils, whether the manure is an acid one such as superphosphate or whether it is alkaline, such as the flour phosphates, always provided that the phosphate becomes active in the soil. This was demonstrated by estimations of acidity made in 1926 on phosphate plots at Borbhetta(4). Naturally the alkaline phosphates such as basic slag and Belgian phosphate have the

greatest acidity reducing power, but even with the acid superphosphates the reduction effected in the soil's acidity is significant. The explanation of this has as yet not been made satisfactorily.

5. *Potash salts.* The effect of potash salts is finally to reduce acidity, on account of the replacement of hydrogen in the clay acid by potassium.

SUMMARY.

1. The soil acidity is due not to free soluble acid, but to colloidal clay and humus complexes. Complex alumino silicates play an important part in the acidity of tea soils in North East India.

2. The "Hopkins", or "lime requirement" method of estimating soil acidity though very useful, may give misleading results especially in the case of soils of low acidity.

3. The pH methods both colorimetric and electrometric, are valuable aids in determining the suitability of a soil for tea and in recommending manurial treatment.

4. The pH of the solution obtained by extracting a soil with a neutral salt solution such as nitrate if potash, is of very great value and this figure taken in conjunction with the pH value of the soil water gives an idea of the "reserve" acidity in a soil. Soils with no "reserve" acidity and very low soil water acidity are unsuitable for tea.

5. The general pH range for good tea soils is pH 4.5 to 6.0 for the soil water, and for the neutral salt extract, pH 3.5 to 5.5.

6. Acidity determinations are of use in deciding whether land is suitable for new planting or replanting of tea, for detecting previous lime treatment and for making manurial recommendations.

7. Sulphur effectively reduces soil acidity but is expensive and in many cases uneconomic in practice.

8. Sulphate of ammonia increases acidity considerably, green crops and organic manures have no appreciable effect, while with potash and soda salts the final result is a reduction in acidity. Phosphates, acid or alkaline, reduce soil acidity.

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SOME NOTES ON THE TREATMENT OF BLIGHTS.

BY

A. C. TUNSTALL.

At the present time, during a period of market depression, there is naturally a tendency to reduce expenditure as much as posible. Under the circumstances there may be a temptation to neglect the treatment of blights. The following notes have been written with a view to pointing out that this would be false economy.

In order to keep the expenditure on this item as low as possible careful management is required, and the question of blight treatment should recevive at least as must care as that given to manuring. It is suggested that definite programmes of blight treatment be drawn up and submitted to this department in a manner similar to that adopted for manuring. The managers concerned may submit suggestions accompanied by specimens of the disease found on their gardens and details of crop etc. in just the same way as they send suggestions regarding manuring. By doing this it would be possible to adjust the recommendations for the treatment of individual diseases so that their application would be simplified.

From the point of view of treatment the diseases of the tea plant may be classed as follows :—

1. Diseases which are the result of lack of vigour of the tea plant.
2. Diseases which are caused by specific organisms which attack apparently irrespective of the condition of the tea plants concerned.

The obvious method of attacking the first kind of disease is by treating the tea plant, by improving the conditions under which it is growing. In this connection it should be remembered that the leaves are essential for the manufacture of the plants requirements. The amount of plant food which can be assimilated by an individual plant is in proportion to its active leaf area. It

is on this account that resting sickly tea bushes by plucking them lightly or not plucking them at all is frequently recommended. Sometimes it is desirable to keep the disease producing organisms in check by direct methods until the increasing vigour of the tea bushes concerned confers a reasonable degree of immunity. More often, however, judicious manuring accompanied by resting is all that is necessary to deal with attacks of diseases of the first category. Such diseases include Brown blight (*Glomerella cingulata*), Grey blight (*Pestalozzia theae*), Red rust (*Cephaleuros Spp.*), Diplodia or tired area disease (*Thyridaria tarda and Diplodia Spp.*) and Violet root rot (*Sphaerostilbe repens*).

In most cases on mature tea plants diseases of this nature do not become serious suddenly and there is no need for them to cause alarm. On young tea, however, Brown blight, Red rust and Diplodia occasionally cause serious damage and on that account it is worth while to pay them immediate attention whenever they are found on such tea. The loss of a single shoot on a young plant having, say, ten shoots only may mean a restriction of at least 10% of its assimilating power. It is therefore very important to protect the leaf area of young plants as much as possible. For this reason it is suggested that nurseries and young clearances be sprayed with lime sulphur solution at frequent intervals during the growing season. On account of the small size of the plants this costs very little. It may be mentioned in passing that the removal of shoots from very young plants with a view to the early development of a frame may seriously interfere with their growth by unduly reducing their leaf area. Whether the reduction in leaf area be due to disease or human agency the result is the same. If insufficient reserve is present in the plant to allow the rapid replacement of the area lost permanent damage will be caused.

On mature bushes the amount of this reserve may be roughly estimated by cutting off a small piece of healthy root. If a drop of tincture of iodine be placed on the cut end the starch reserve in the wood will go black. The degree of blackness may be taken as a measure of the amount of starch present. The wood of the

roots of a healthy vigorous bush will go almost black if treated in this manner.

If the reserves are insufficient to enable the plant to produce new shoots it will remain banjhi until sufficient reserves have been accumulated to enable the new leaf to be produced. During this period of slow growth Brown blight and Red rust frequently make matters worse by reducing the leaf area. The protection of the green parts of the plant by spraying with lime sulphur is then very valuable. It will not prevent the banjhi period but will tend to shorten it by preventing fungi from reducing the leaf area.

Before leaving this class of diseases special reference may be made to Violet root rot (*Sphaerostilbe repens*). This disease is very common on old tea growing on soils containing a high percentage of the finer particles. The fungus is very common in the soil and under ordinary circumstances appears to do no harm to the tea plants. It has been frequently noticed that an attack of this disease is preceded by the death of many of the deeper roots of the bush concerned. The death of these roots does not appear to be caused by a parasitic organism. If the bushes are carefully nursed new roots form nearer the surface and although the deeper one may decay right away the bush continues to live. It frequently happens that the bushes have gone too far before treatment is started and although in time they may recover the process is too long to be economical. In such cases it is better to replant the area concerned. Although the new plants do not produce deep roots they grow quite satisfactorily.

To summarise—diseases due to the debility of the tea bush do not as a rule cause very serious losses on mature tea and the progress of the diseases concerned is usually slow. This is fortunate as it allows time for the influence of improvements in cultural conditions to have effect, before serious losses have been incurred. As a general rule it does not pay to treat such diseases by direct methods such as spraying. In times of crop restriction the most satisfactory method of treatment is by resting the

bushes concerned either for the whole or part of the season. Young plants and others on which the leaf area is small should be treated directly by spraying.

Diseases which are caused by organisms which attack apparently irrespectively of the condition of the tea plants concerned require to be treated as soon as possible. It is false economy to postpone treatment on account of expense. Constant attention to small outbreaks is essential. If no effort be made to check diseases of this nature it is found by practical experience that in many cases the amount of damage is limited. For instance root diseases if allowed to extend unchecked many cause the death of two or three bushes per acre per annum. Black rot (*Corticium invisunn*, *Corticium theae*), if untreated, will cause an annual loss of two or three maunds of tea per acre. Stem diseases require about ten years to render a piece of tea unproductive. This is probably due to the fact that optimum conditions of temperature, humidity etc., for the growth of an individual fungus are fairly well defined and such conditions only occur for limited period during the year. Although a fungus is able to grow throughout the year it is only when conditions are near the optimum that rapid extension takes place. As a clear example of this the case of Blister blight may be taken. The fungus which causes this blight requires high humidity and comparatively low temperature for rapid growth. In most of the tea districts these conditions only occur together for a very short period during the year hence this disease does not, as a rule, causes serious loss. Although there is a natural check on the progress of most diseases it obviously does not pay to leave nature to do the work. By the immediate treatment of small outbreaks it is usually possible to prevent, with a minimum of expense, any diseases of this kind from doing serious damage. Even assuming that the disease concerned has been allowed to become general the cost of the treatment is very small compared with the losses avoided.

If root disease has been allowed to go on unchecked it will take about five years steady work to reduce the losses to a mini-

mum. The common root diseases which attack the tea plant irrespective of its condition are Brown root rot (*Fomes lamaoensis*) and Charcoal stump rot (*Ustulina Zonata*). Both of these as a rule spread below ground from root to root. It is probable that it is possible for the fungi concerned to spread from root to root without actual contact between the roots concerned. Experience has shown however that the removal from the soil of all dead roots and any apparently healthy bushes whose roots are actually in contact with the infected wood successfully eliminates the disease from that particular spot. It is therefore recommended that wherever a bush dies from either of the above diseases this procedure be adopted immediately.

Diseases of the woody branches in most cases are associated with dead snags. So far it has not been found possible to devise a system of pruning which avoids the production of any snags. The policy of leaving heavy pruned tea unpruned in the year following the heavy pruning is on this account very bad. Sufficient growth should be left on the heavy pruned tea to yield satisfactory pruning wood in one season. This in itself will help the wounds to heal. It is however of great importance to cut off dead snags to clean wood as soon as possible. Large wounds may be painted with wood tar but to be effective the paint must be renewed every cold weather until the wound is healed.

Diseases caused by fungi such as *Nectria cinnabarina*, *Macrophoma theicola etc.*, which are not necessarily associated with dead snags on the tea plant require to be cut out as soon as discovered. At the same time all dead and moribund wood on shade and jungle trees in the vicinity should also be removed and burned. Any dead logs, branches etc., lying about in the vicinity of the outbreak should be removed at the same time as they may serve as centres of infection for such diseases.

Of diseases which attack the green parts of the tea plant, Black rot (*Corticium invisum, Corticium theae*) is the most important. Its resemblance to Brown and Grey blights often causes

it to be overlooked until the drop in crop is obvious. It is very important to deal with small outbreaks without delay as the fungus spreads with great rapidity. The infected bushes should be treated as soon as noticed by thoroughly spraying them and their neighbours with lime sulphur solution. The spraying should be repeated a week later. Wherever this disease is known to occur a special gang of coolies should be constantly employed to deal with small outbreaks. For such purposes it is desirable to use commercially made lime sulphur solution as experience has shown that unless this solution is prepared under good supervision its value is much reduced. It is impossible to supervise the preparation of small quantities properly without undue loss of time. At the time of pruning all bushes found to be attacked by Black rot (*Corticium invisum, Corticium theae*) should in the case of areas being pruned be left unpruned until the uninfected bushes have been finished and their prunings buried. The infected bushes should then be pruned and the prunings removed to the nearest hullahs and burned. These bushes should then be sprayed thoroughly with lime sulphur solution. These bushes will be easily distinguishable for some time after pruning and they should be sprayed again after the first rains have fallen. In the case of areas to be left unpruned the infected bushes should be pruned and treated as suggested above. Bushes attacked by Thread blight may be treated in a similar way.

The cost of treating small outbreaks is obviously smaller than that involved in treating large areas. To be effective it must be carried on throughout the year and must be done very thoroughly. This means more supervision than is necessary for the treatment of large areas during only one period of the year.

Summary.

During periods of market depression the treatment of blights should not be allowed to lapse on account of expense.

In the case of diseases which are due to the debility of the tea plant mature plants with a large leaf area may be treated by cultural methods. Young plants and others with restricted leaf

area require treatment with fungicides whenever a disease threatens undue reduction of leaf area.

Diseases which attack tea plants irrespective of their condition require constant attention and the best way to restrict expenditure is by careful attention to small outbreaks, thus obviating the necessity for treating large areas.

Programmes for disease treatment accompanied by specimens of the diseases concerned and other relevant details may be submitted to the department for criticism.

THE TOCKLAI GUEST HOUSE.

Opinions have been expressed that the charge for the use of the Guest House, namely Rs. 20 per day, was excessive. This rate was fixed with a view to the formation of a reserve against up-keep expenses. Apart from its use during the Courses of Instruction, however, the Guest House has been made little use of by members so that the total receipts from occasional occupants have been barely sufficient to pay the staff of servants maintained.

With a view to encouraging more frequent visitors the Scientific Department Sub-Committee of the Indian Tea Association Calcutta have decided to reduce the charge to Rs. 15 per day with full messing.

In cases when the Guest House is not used for a full day, charges will be made on the following scale :—

Use of bedroom	...	Rs.	5	0 0
Morning tea	...	,,	0	8 0
Breakfast	...	,,	2	0 0
Tiffin	...	,,	3	0 0
Afternoon tea	...	,,	0	8 0
Dinner	...	,,	4	0 0
TOTAL	...	Rs.	15	0 0

Intending visitors are requested to give twenty-four hours notice of their arrival, since it is impossible to maintain stocks of food while visitors are infrequent.

THE EFFECT OF MANURING ON THE QUALITY OF TEA.

BY

H. R. Cooper and C. R. Harler.

When the market falls attention is always focussed on the quality of tea.

Men of long experience generally state confidently that the teas now on the market are definitely inferior to those from the same gardens about 25 years ago. A falling off in the standard of plucking is often referred to, but manuring very often receives an almost equal share of blame.

Crop per acre has been increasing, and manuring very rightly is credited with a large share in the responsibility for the increase. So commonly is it true that marked advantage in one direction is accompanied by disadvantage in another, that it is asserted, in many quarters, almost as if it were an axiom, that increasing crop must be accompanied by decreasing quality.

The proposition that big crops are of poor quality receives support from the known fact that extremely rich soils such as virgin *bheels* in the Surma Valley, do produce huge crops (20 maunds per acre and over) selling at a low price. Yet it is not true that the higher the yield the poorer must be the quality.

If one writes down the plains districts of North East India in order of yield per acre, one certainly does not find those getting the highest average prices at the bottom of the list. It is much more nearly true that the higher the yield, the higher is the average price obtained by the district. It is also true that of the gardens selling at stand-out high prices, many also produce very high yields.

There is very clearly no foundation for the charge that moderately high yields, such as for example the average crop for Upper Assam in 1929 (9 maunds per acre), must necessarily be of poor quality. A yield of 9 maunds (720 lbs.) per acre does

not by any means indicate a forced rate of growth. Any normally healthy, mature tea will give at least that yield without coarse plucking. Mature areas plucked as average Assam gardens are (not absolutely strictly), which give much less than 9 maunds per acre, carry tea which is either in poor condition or contains too many vacancies.

Therefore to suggest that manuring should be reduced below its present average level, is to suggest that tea should be starved into poor condition.

A crop of even 8 maunds per acre removes from the soil about 32 lbs. nitrogen annually. This quantity of nitrogen is supplied by 2 manuds of sulphate of ammonia or 9 maunds of oilcake. These are considered good dressings by the standard of recent average manuring in tea, yet it is seen that they do no more than replace what is removed from the soil by a very moderate crop.

It is true that natural agencies supply some nitrogen to unmanured soils, but even a crop of 8 maunds per acre could not be maintained indefinitely without some form of manuring.

During the times when average crops in North East India were no more than 4 to 6 maunds per acre, the sporadic manuring practised allowed soil nitrogen to drop from an average of about ·15% to between ·08 and ·10%, with consequent deterioration of the tea. A return to these *jhum** methods, would indeed reduce the crop on the market not only by reducing crop per plucked acre, but by adding to the already large area of unremunerative or abandoned tea. The reduction in crop would doubtless affect prices for the better, but at present costs of labour and materials generally (other than manures which are now very cheap) the cost of production per pound from the smaller yields would be so increased that the profit per pound might show a decrease.

In our opinion manuring of tea in North East India has been not excessive, but even deficient. There are many brilliant

* Note—*Jhuming* is an agricultural method practised by hill tribes whereby crops are grown till the soil is exhausted, when the land is allowed to revert to jungle and other virgin areas cleared.

exceptions (and these companies do not produce the worst tea) but for the greater part of our area, tea production would be more remunerative if manures were used more liberally and more systematically. There is no evidence in favour of the charge that the general increase in crop has been accompanied by a decrease in quality due to the forcing of growth by excessive manuring.

A more specific charge is sometimes made that certain manures have an adverse effect of quality. The soluble, quick-acting nitrogenous manures, sulphate of ammonia and nitrate of soda particularly, lie under suspicion. This suspicion has several times been referred to the Scientific Department by particular companies which have made large crop increases, and are now obtaining prices lower in comparison with the average than were obtained when crops were lower. Such cases provide evidence which must be considered very seriously. On the other hand we know of several companies using even larger quantities of the same manures which have maintained or even greatly raised their position in the lists of average tea prices, in spite of increased crop.

There is no known reason why one form of nitrogen should have a worse effect on quality than another. The effect of a nitrogenous manure both on crop and quality depends on the concentration of nitrate produced in the soil. The soluble manures produce a high concentration of soil nitrate more easily and more rapidly than less soluble manures, and therefore produce larger and more rapid crop increases than organic manures. If there is a greater falling off in quality consequent on the crop increase it must be due to greater and more rapid crop increase from the more efficient manure. Any objection to a manure on the score of its over-efficiency could be met by using smaller rates of application.

Similar charges of over-rapid crop increase and consequent fall in quality, are frequently brought with even more force against the very slow acting peat soil, when this is used in excessive quantities.

It appears therefore that there is general evidence to indicate that excessive nitrogen, in any form, may force over rapid growth of poor quality.

Since this is in agreement with what is known on other crops it may be accepted as true. In the case of crops valued on their content of some easily estimeted substance the question is easily examined. With sugar beet for example, while doses of nitrogen producing moderate crops make little difference to the sugar content of the root, any large dressing of nitrogen lowers the percentage of sugar in the roots, although it generally increases the total sugar per acre by increasing crop in a much greater ratio than sugar percentage is decreased. It has been observed, however, that the sugar content falls off markedly when so much nitrogen is applied that it ceases to increase crop. Anything approaching such excess is certainly to be avoided.

The questions of practical importance which remain to be decided, are how much manure may be used without causing distinct loss of quality, and what is likely to be the loss in price per pound consequent on increasing crop by the use of a particular dose of active nitrogen.

The varied experiences of different gardens, already referred to, indicate that the answers to these questions will depend upon other factors in addition to the amount of manure used, or the rate of increase in crop produced. From what we know of the systems of work on these gardens, it may be inferred that among these other factors, the system of plucking is of paramount importance, and from general principles the differences caused by differences in plucking probably may be guessed fairly accurately.

As an illustration we may consider the extreme case of tea growing so poorly that when plucked at nine days interval the great bulk of the crop is just ready two leaves and a bud. If that tea were so manured that in nine days a very large percentage of the crop consisted of three leaves and a bud, and all were taken, a very large increase in crop would be obtained, and a large

decrease in quality. Even if only two leaves and bud were taken, and the third broken back, it is probable that quality would still be lowered, though to nothing like the same extent.

If however, the intervals between pluckings were so decreased that the leaf were just ready when taken, it might happen that the manured tea would give as much ready leaf—say—every six days as the unmanured tea would in nine days. In that case one would obtain a fifty per cent increase in crop, and it would be expected that quality would suffer little, if at all. It is indeed highly probable that in such a case quality might be found to improve, since with nine days plucking a number of the shoots even from poor tea must be over-ready, while there would be little or no over-ready leaf after six days even from heavily manured tea.

If the unmanured tea also were plucked at six days the tea from it would be expected to be better than the six-day leaf from the manured tea; but plucking at short intervals on poorly yielding tea is seldom practicable.

As a summary of our opinions on the effect of manuring on quality we would say that manuring probably would lower quality if all other factors remained equal, but that plucking can make a bigger difference than manuring. In practice it does appear that relatively heavy manuring (even with soluble artificials), accompanied by finer plucking at closer intervals, can give large increases in crop of quality equal to or better than that for the same tea unmanured.

At Borbhetta we have a block of Burma tea under manuring experiments. Different plots receive annual doses of nitrogen varying from *nil* to 120 lbs. per acre. The quantities of potash and phosphoric acid also vary. The unmanured tea bushes are small, thin and "empty" looking: the leaf is yellowish. The yield is dropping steadily but is still much better than it would be from similarly fed tea on most gardens because there are no vacancies or weak bushes, and cultivation, pruning etc.,

are of the best. The more heavily manured plots are well filled by big bushes, all dark green, healthy, and full of yielding shoots.

Most of the comparisons of quality were made between completely unmanured tea giving 9 maunds an acre, normally manured tea giving 13 maunds, and heavily manured tea giving 18 maunds an acre.

The further increase of crop from plots receiving 120 lbs. nitrogen was so small that a large decrease in quality might be expected. Applications as large as 90 lbs. nitrogen per acre, so far as we are aware, are never made on gardens in practice, so that if there is marked decrease in quality from manuring it should show on these plots.

The following reports made by tea tasters on teas manufactured from leaf plucked off manured and unmanured bushes gives some idea of the effect of manuring on quality.

The manures were added in the form of sulphate of ammonia, superphosphate and muriate of potash. A normal dose of such manures in North East India is about 150 lbs. sulphate of ammonia, 150 lbs. superphosphate and 60 lbs. muriate of potash per acre, giving 30 lbs. nitrogen (N), 30 lbs. phosphoric (P_2O_5) and 30 lbs. potash (K_2O) per acre.

In the experiments detailed below all conditions were, as near as practicable, the same for each experiment. The finished teas were roughly sorted into two grades, fine and coarse, since full sorting machinery is not yet installed in the Tocklai experimental factory. With the heavily manured teas the fine grades were about 55% of the bulk against about 45% with the unmanured teas.

The teas were reported on by three separate Calcutta tasters.

EXPERIMENT I.

Tea was manufactured in August from leaf taken from unmanured and heavily manured areas.

A—unmanured.

B—heavily manured, $N/P_2O_5/K_2O = 90/90/90$ lbs. per acre.
lbs. per acre.

First Taster's Report.—

Leaf—The rough leaf is similar in both cases. In the fine leaf B has much better tip, an important consideration.

Infused leaf—A are much brighter and more even.

Liquors—A are preferable, being much stronger and thicker.

Valuations—The B samples were valued about ¼ anna (¼d.) a pound higher than the A samples, on account of the tip.

Second Taster's Report.—

Leaf—The coarse leaf is bold, open and similar in both cases. In the fine leaf B has more tip.

Infused leaf—The A samples are bright, mixed and greenish. The B samples are dark green.

Liquors—The A samples have preferable liquors with more colour and strength. The B samples have light liquors which are raw and immature.

Valuations—The B samples are valued about ½ anna a pound better than the A.

Third Taster's Report.—

Leaf—The A samples are slightly smaller than B, and have preferable twist and make.

Infused leaf—A are fairly bright and even whilst B is dark and sweaty.

Infusion—A is preferable to B, with more colour, body, strength and quality. B is plain and dry in character.

Valuations—The A samples are valued 1 to 1½ annas better than the B.

EXPERIMENT 2.

Tea was made in September from unmanured, normally, and heavily manured areas.

A—unmanured.

B—$N/P_2O_5/K_2O = 30/30/30$ lbs. per acre.

C— ,, ,, $= 90/90/90$,, ,, ,,

First Taster's Report.—

The liquors of A are brisk, but rather light and raw, and C, though more coloury, are softer and inferior. The B liquors are more distinctly brighter and have more even infused leaf than either A or C.

The B samples were valued about ¼ anna better than the A and ½ anna better than the C samples.

Second Taster's Report.—

A—Has most tip and second best liquor.

B—Has the best liquor, but least tip.

C—Has good make but poor cup.

The A samples were preferred, and valued about 2 annas a pound better than B, and 1 anna better than C.

Third Taster's Report.

A—Good make, green infused leaf, light liquors with quality.

B—Even, bright infusion, thick liquors.

C—Even, dark infusions, tippy.

The B samples were preferred because they were a better "commercial" type, and valued 2 annas above A and 3½ annas above C.

EXPERIMENT 3.

This experiment is a repetition of experiment 2, carried out a week later.

A—unmanured.
B—$N/P_2O_5/K_2O = 30/30/30$ lbs. per acre.
C— ,, ,, $= 90/90/90$,, ,, ,,

First Taster's Report.—

Leaf—Of the coarse leaf, all samples are rather open, but C is the worst in this respect, though blackest in leaf. A and B are similar.

Of the fine leaf A and B are about equal, both having a little tip, but C has considerably more tip and is consequently preferable.

Infused leaf—All are uneven. That of C is definitely the darkest. There is little or no difference between A and B.

Liquors—A are little stronger and slightly preferable to B, C is definitely the worst, being softer and plainer than A or B.

B and C have the same valuation and A is better than both by about ½ anna a pound.

Second Taster's Report.—

A—Shows the best liquors and second best leaf.
B—Second best liquors and worst leaf.
C—Poorest liquors but best leaf.

The nominal prices show the A samples ½ anna a pound better than C and 1 anna better than B.

Third Taster's Report.—

Owing to delay in receipt of the samples, they had "gone off" before this taster examined them. B appeared to be preferable to the others, however.

EXPERIMENT 4.

This was a repetition of experiments 2 and 3, made at the end of September.

A—unmanured.
B—$N/P_2O_5/K_2O = 30/30/30$ lbs. per acre.
C— ,, ,, $= 90/90/90$,, ,, ,,

First Taster's Report.—

Leaf—The B samples have the best twist but least amount of tip. The A samples have the most tip, followed by C.

Infused leaf—The B samples are the brightest and most even, followed by C, then the A samples.

Liquors—The B samples have easily the best liquors, the best quality, strength and body. The C samples are the next best, but considerably inferior to B.

The A series are soft and plain with very little strength and colour and are much inferior to the others.

The taster remarked that this series is different from the others, in that the unmanured has the tip and the manured teas the liquors.

The B sample is valued about ½ anna a pound more than C and 1 anna better than A.

Second Taster's Report.—

A—Most tip but poorest liquors.
B—Least tip and best liquors.
C—Intermediate between A and B.
The A sample was valued about ½ anna a pound better than B and C, which were equal in value.

Third Taster's Report.—

Leaf—There is little to chose between the A and C samples in the coarse leaf, but the B samples are coarser than either.

In the fine leaf, the C samples show more tip than A which, in turn, shows more than B.

Infused leaf—The B samples are more even and have better colours than the A or C samples. The A samples are bright, but rather green, whilst the C samples are inferior, being dull and discoloured.

Liquors—The liquors of the B series are preferable to the A and C series, because they are "round", with a little quality and more colour than either A or C. The A samples are stronger than B, which is light and lacking in body. The C samples are the worst, being plain and characterless.

The B sample was valued 1 anna a pound better than C and ½ anna better than A.

Taking these reports in a very general manner, it is seen that the heavily manured areas usually gives teas with preferable leaf but inferior liquors to those from unmanured or lightly manured areas. The tea on both manured and unmanured areas was plucked at 7-day intervals. In this time the heavily manured tea was over ready and had to be broken back in many cases. Had plucking on the manured areas been at 6-day (or at times even 5-day) periods, these teas might not have shown any inferiority in liquors.

EXPERIMENT 5.

Leaf was manufactured in August from two areas, one of which was manured with an unbalanced manure and the other with a balanced one.

A—manure $N/P_2O_5/K_2O = 90/30/30$ lbs. per acre.

B— ,, ,, ,, $= 90/90/90$,, ,, ,,

First Taster's Report.—

Both samples are inclined to be raw and green. The B samples are stronger, brisker and more coloury than the A, which are softish.

The B samples are slightly higher priced, about ½ anna a pound, better than the A samples.

Second Taster's Report.—

The A samples have the better liquors and give brighter infused leaf.

The B samples have better leaf with more tip. The liquors are, however plain and characterless.

The preference in price of about 1 anna a pound is given to the B samples.

Third Taster's Report.—

A has preferable make and appearance and shows more quality than the B sample.

The A samples are valued ½ anna a pound more than the B.

The tea receiving the unbalanced manure yielded 15 maunds an acre against 18 maunds given by the area receiving the balanced manure. Here again, the areas were both plucked at 7-day intervals and a slightly shorter round would have improved the teas made from the higher yielding area.

These experiments as a whole indicate that manuring generally has no great effect on quality so long as plucking is fine, and at close intervals.

TOURING PROGRAMME 1931.

Month.	P. H. Carpenter.	H. R. Cooper.	C. R. Harler.	C. J. Harrison.
January ...	Imp. Agri. Council General Meetings Dooars and Terai	N. Lakhimpore	Dhunsiri, Golaghat	Tulsipara Tea Estate
February ...	.....	.....	Lakhipore General Meeting Surma Valley	.....
March ...	Calcutta General Meeting Darjeeling	Balisera, Luskerpore		Tulsipara Tea Estate
April ...	.....	.....	H	Hailakandi, Chutla Bheel
May ...	Sonari	.....	O M E	.....
June ...	Imp. Agri. Council	Mal, Oodlabari		.....
July ...	Calcutta	.....	L E	N. W. Cachar, North Surma
August ...	.....	.....	A V E	.....
September ...	Chulsa, Nagrakata	South Darjeeling		.....
October ...	.....	.....		Mangaldai
November ...	Calcutta	.....	.....	.....
December ...	.....	.....	.....	.....

N.B.—The other Officers of the Department will tour only as the investigations that they are carrying out necessitate.

The exact dates of the above tours will be given later to the Sub-District Chairmen. Managers desiring a visit from the Scientific Officer must inform the Sub-District Chairman who will make out a tour itinerary.